INSTRUCTION MANUAL

KEITHLEY INSTRUMENTS, INC.
CLEVELAND, OHIO

MODEL 303

DC INDICATING AMPLIFIER AND ACCESSORIES

KEITHLEY INSTRUMENTS, INC.

CLEVELAND, OHIO

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SECTION I INTRODUCTION

The Model 303 DC Indicating Amplifier is a high gain electrometer voltmeter and dc amplifier for the frequency range of dc to 100 kc.

Its outstanding characteristics are an input resistance of greater than 10^{12} ohms shunted by approximately 10 mmf., grid current of less than 10^{-12} amperes, direct reading of the input signal by means of a large panel meter, exact gain steps stabilized by negative feedback, a differential input, low drift, and an output which will drive most pen writers and galvanometers. The full-scale ranges are from 0.002 volt to 2.0 volts.

The many features of the Model 303 make it a very desirable instrument for making general-purpose laboratory measurements of low-level dc and ac signals.

The extremely low grid current and ultra-high input resistance of the Model 303 make it outstanding for accurate low-level measurements in circuits with impedances in excess of about 100,000 ohms. Most commercial dc amplifiers have grid currents of 10^{-8} amperes and greater. Grid current of this magnitude flowing through a network having a resistance of 100,000 ohms would cause the generation of a one-millivolt spurious signal. If the resistance in the measuring circuit were raised to ten megohms, the spurious signal would amount to 100 millivolts. Considering that 10^{-8} amperes is a conservative figure for receiving tube grid current, surprisingly great inaccuracies in measurement can be caused by assuming that a vacuum tube grid circuit is passive in nature. Fig. 1 is a chart of these errors for various grid currents and source impedances.

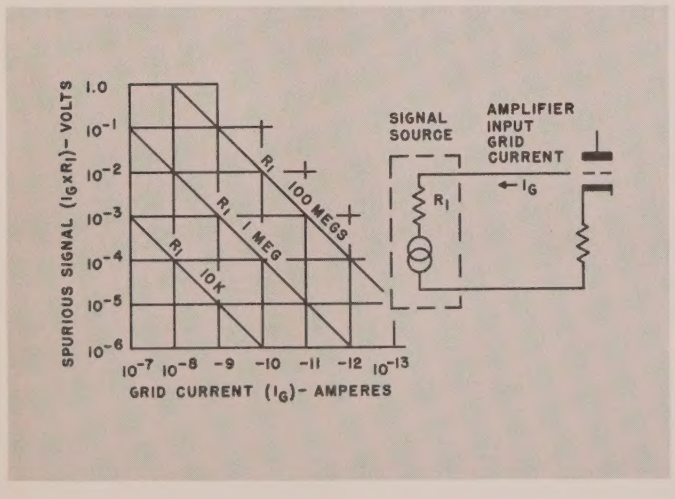

Figure 1. Errors caused by high test-instrument grid current when measuring several source impedances. Keithley 303 grid current of 10^{-12} amperes is about 1/10,000th as large as the grid current of typical dc amplifiers. In addition to masking a signal, grid current can make it appear to vary, for random changes in grid current will appear as drift on a chart record.

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The Model 303, therefore, is a voltmeter and amplifier which measures signals in low-voltage, high-impedance circuits with substantially less bothersome error due to low input impedance or grid current.

Several accessories which plug into the lower left hand corner of the panel greatly extend the usefulness of the basic instrument. The first is the Model 3034 Decade Shunt which converts the Model 303 into a micromicroammeter for measuring currents as small as 10^{-12} ampere. Others are multipliers which extend the measuring ranges up to 800 volts.

A test jack at the back of the chassis gives a stable test potential of 200 volts which can be used for polarizing photocells and ion chambers and for providing the potential across an insulation sample. The resulting leakage current is a measure of the resistance of the insulation.

The Model 303 with its accessories functions as an accurate, sensitive, wide-range voltmeter; as a micromicroammeter; and as an ohmmeter. It is a general-purpose amplifier and a recorder driver as well. This one, versatile, instrument fulfills most dc measurement requirements encountered.

SECTION II DESCRIPTION

The Model 303 Amplifier consists of three major parts; a voltage amplifier driving the panel meter, a power output amplifier, and the power supplies.

The voltage amplifier consists of a balanced electrometer first stage followed by three stages of balanced pentode amplification. The open loop gain of the voltage amplifier is approximately 600,000. Inverse feedback varies the working gain from a maximum of 15,000 to a minimum of 15. The feedback factor, correspondingly, varies from about 40 on the most sensitive to 40,000 on the least sensitive range. As the sensitivity is decreased, there is an increase in frequency response. With a feedback factor of 40 on the most sensitive range, the upper 3 db point is about 20 kc.; on the least sensitive range; where the feedback factor is about 40,000, the upper 3 db point is in excess of 100 kc.

Since gain is changed by varying the amount of inverse feedback, the signal to noise ratio remains constant on all gains; and the drift, referred to the input, is constant no matter what the range. In contrast to this, changing the gain by means of an input attenuator would increase the signal to noise ratio and correspondingly increase the rate of drift referred to the input.

The feedback factor of the voltage amplifier is high enough on all ranges, and sufficiently stable resistors are used so that a change in gain of substantially less than 1% can be expected on any range throughout the life of the instrument. It is therefore unnecessary to provide a means of calibrating the voltage amplifier or to provide a control for adjusting its gain. For this reason the accuracy of the panel meter readings will not change over the life of the instrument and no more attention to meter calibration is necessary than with a sensitive AC vacuum tube voltmeter.

The cathode-follower output of the voltage amplifier drives the meter and supplies the signal voltage for the power amplifier.

The power amplifier has two stages of voltage amplification and a power output stage which consists of a cathode-follower with a constant-current cathode load. The open loop gain of this amplifier is about 200 and the working gain is reduced to 12 by means of inverse feedback. The input signal to this amplifier may be varied by a factor of about four with an input potentiometer (output gain) so that recording devices may be set at any desired sensitivity. Calibration signals are provided for the power amplifier (see Fig. 5 page 11) which correspond to quarter and half scale meter deflections, in order that the power output and attached recorder may be standardized in terms of meter sensitivities. Since, as stated above, the voltage amplifier (meter amplifier) has stabilized gain, it is necessary to calibrate only the power amplifier to determine recorder sensitivity accurately. For ready reference, a chart on the panel above the range (millivolts) switch displays the effective value of the calibration signal in terms of signal at the input. Hence, for a recorder, the coarse gain control is the Millivolts switch, and the fine control is the Output Gain.

The power supply consists of two transformers, three rectifiers, and two three-stage electronic regulators. The B+ and regulated filament supply is furnished by one, and the B- by the other regulator. The low drift and freedom from effects due to voltage variations are, to a great extent, due to the high inherent stability of the power supplies.

INPUT CONNECTIONS

The input compartment is located in the lower left corner of the panel. It will accommodate the various input accessories described below as well as the STANDARD INPUT. In all cases a protective one-megohm resistor shunted by 0.005 mfd is connected to the grids of the input stage. Fig. 2 is the circuit schematic drawing of the input and Fig. 3 shows a Model 3034 Decade Shunt being plugged into position.

1. Standard Input: Direct connection is made from the input terminals to the grids of the first stage tubes through 1 megohm shunted by 0.005 mfd. For balanced operation both input terminals are used. For single ended operation input B is shorted and input A is used.

2. Model 3032 Multiplier provides range multiplication ratios of 1X, 10X, 100X and 1000X, selected with a small rotary switch, thus adding ranges of 8, 20, 80, 200, and 800 volts. Precision wire-wound resistors are used; the input impedance is 1.0 megohm; accuracy of the ratios at dc is 0.2%; frequency response DC to 30 kc.

3. Model 3033 Multiplier is similar to the 3032 except that deposited carbon resistors are used, and the input impedance is 100 megohms; accuracy at dc 2%; response, dc to 1 kc.

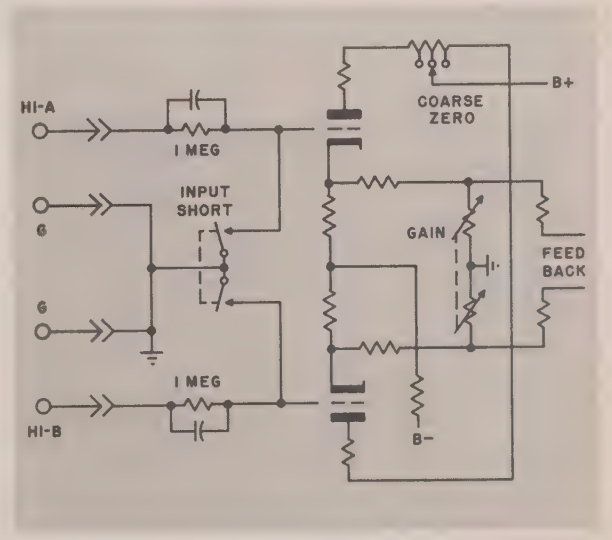


Figure 2. Simplified diagram of input circuitry showing electrometer inputs, use of balanced circuits, input shorting switch, zeroing connections and feedback gain control. Input tubes are mechanically shock mounted.

4. Model 3034 Decade Shunt converts the 303 into a direct-reading micromicroammeter. Seven ranges are provided in decade steps, from 10^{-6} to 10^{-13} ampere, plus short and open positions. Accuracy on the two most sensitive ranges is within 2%, and within 1% on all other ranges. The current being measured equals the meter reading in millivolts multiplied by the switch position on the decade shunt.

The short position provides a convenient switch step when zeroing the instrument and prevents upsetting the system when making changes in the input connections. The open position permits voltage measurements to be made with minimum circuit loading, and without removing the Shunt.

CONTROLS AND ADJUSTMENTS

The following controls and adjustments are provided on the panel:

1. Zero consists of three controls which are located in the left upper section of the panel. They are COARSE and MEDIUM step switches and a FINE control, which employs a ten turn potentiometer. The function of these controls is to make the meter read zero when the input is zero. Zero may be taken to mean the left zero of the meter or any other point on the meter with the exception that maximum deviation from the left meter zero on the 2.0 volt range with no input signal should not exceed one volt. On all other ranges the pointer may be "zeroed" at any point on the scale. In addition to setting the zero with no signal present on the input, it is permissible to use these controls to balance-out, or suppress, a steady dc signal when only small variations in this signal are to be studied. The maximum signal which may be suppressed is one volt. This operation may be performed at any voltage sensitivity and consists of adjusting the balance controls until the meter reads on scale at the selected sensitivity. The ZERO control calibrations on the panel are approximately correct and are intended as a guide for the user; but they should not be used for accurate measurement.

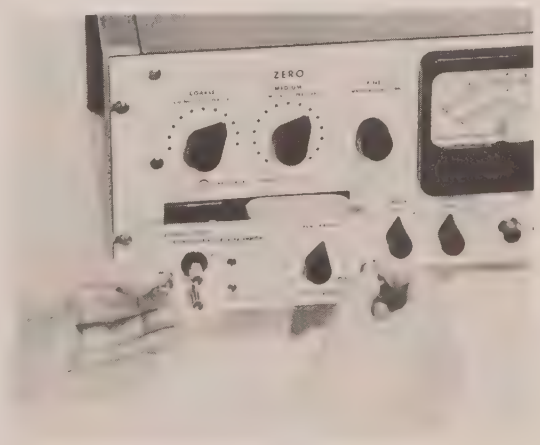


Figure 3. Accessory multipliers or Decade Shunt are quickly interchanged with standard plug-in input panel. Multipliers extend voltage range to 800 volts shunt permits measurement of current down to 10^{-12} amperes.

2. Input Short This control is located directly below the COARSE ZERO control. Pushing it shorts the input grids to ground. One megohm is in series with the input terminal to limit the current which can be drawn from a low impedance source.

3. Millivolts This is the range switch; in addition to setting the meter sensitivity, the MILLIVOLTS switch is also the coarse gain control for a metering or recording system connected to the output terminals.

4. Meter This switch disconnects the meter or reverses its polarity. In the + position, positive potential on the Hi-A terminal causes an up-scale reading.

5. Output Cal This control is to the right of the METER switch. In the OPER position, the power output amplifier receives the output signal from the voltage amplifier. This signal appears, amplified, on the OUTPUT terminals. In the ZERO position, the input of the output amplifier is grounded. CAL A position presents a signal equivalent to one quarter full scale, and CAL B a signal equivalent to one half full scale meter deflection to the input of the power amplifier. The magnitude of the CAL A and CAL B signals are tabulated under MILLIVOLTS. The ZERO position can be used when turning off the recorder and should always be used when changing ranges to prevent damage to the recorder.

6. Output Gain This control is located at the lower right of the panel, and adjusts the gain of the output amplifier over about a 4 to 1 range. It allows continuous adjustment of recorder sensitivity.

7. Alignment These screw driver adjustments are located between the power switch and the OUTPUT GAIN. ZERO controls the zero of the output amplifier, and BAL controls the voltage level at which the balanced meter circuit operates. Their purpose is to set the output to zero when the panel meter is zero (at the left of scale) and keep the output at zero (with meter at zero) when the OUTPUT GAIN is rotated. See page 11.

The following adjustment is located at the rear of the chassis: +200ADJ: This potentiometer is set so that B-plus is at 200 volts plus or minus 1%. Normally no additional attention is necessary unless the voltage reference tube (V22) is changed. Since the accuracy of the calibration voltage depends on the accuracy of the B-plus, the 200 volt calibration should be checked occasionally.

The R_S, R_D, and Equal terminals are discussed on page 10.

The R_s (resistor in series with the galvanometer) and R_d (resistor shunting the galvanometer) terminals on the rear of the chassis provide a convenient place for attaching attenuator resistors. The connection of R_s, R_d and the output terminals is shown in Fig. 4.

The value necessary for R_d should be obtained from the recorder manufacturer's specifications.

The value of the series resistor required may be computed from the following formula:

$$R_s = \frac{80}{I_G \times 10^{-3}}$$, where R_s is the series resistor in ohms, and I_G is the current in milliamperes through the galvanometer the R_D in parallel necessary for full scale deflection.

The following table gives R_s and R_d values for several popular types of recorders:

Instrument	R_d Ohms	R_s Ohms
Cathode Ray Oscilloscope	infinite	zero
Brush Electronics BL902	2200	2300
Sanborn Company 51-500	infinite	zero
Esterline-Angus 0-1 ma	infinite	80K
Esterline-Angus 0-5 ma	infinite	15K

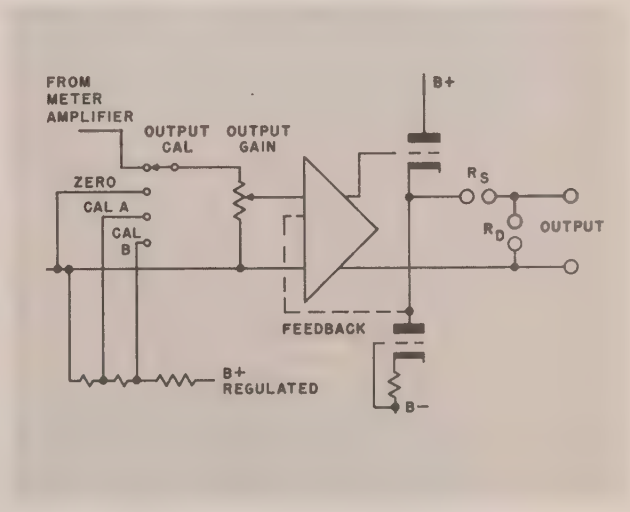


Figure 4. Simplified diagram of output circuitry. R_s and R_d are connections for series and damping resistors to attenuate output to match recorders.

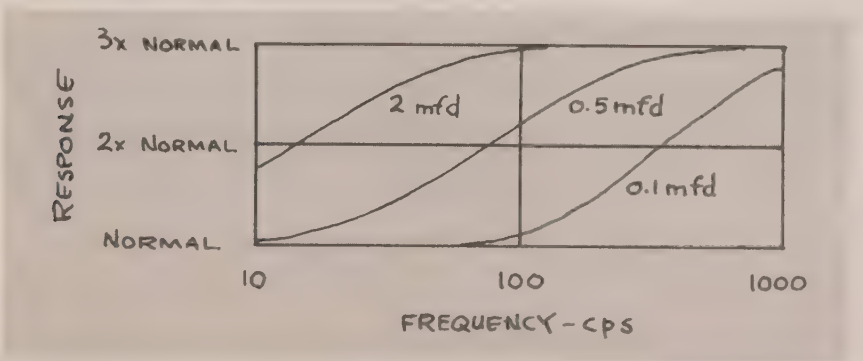
(b) Equalization of Recorders: In addition to the R_s and R_d terminals at the rear of the instrument, Equalizer terminals are provided. The purpose of these terminals is to allow the user to peak the high frequency response of the output amplifier sufficiently to compensate for fall-off in the high frequency response of a particular recorder by connecting a capacitor across the terminals. The Equalizer terminals are in series with 2.2K ohms, which is across the shunt element of the power amplifier feedback network. The maximum peaking is limited to three times normal gain by the 2.2K resistor, and the frequency region in which the peaking will occur is determined by the size of the capacitor placed across the EQUALIZE terminals. Fig. 5 gives representative responses for various values of capacity.

(c) Operation with recorder: Place the Model 303 in operation as described previously. Turn OUTPUT CAL to the Zero position, and attach recorder after connecting proper R_s and R_d resistors. There should be no movement of recorder from its normal zero point. If there is, adjust recorder to zero by means of ZERO screwdriver adjustment under ALIGNMENT on front panel. Now adjust panel meter to read at its left zero position with the ZERO controls and turn OUTPUT CAL to OPER. Again the normal zero of the recorder should not shift. If it does, adjust the recorder back to zero with BAL screwdriver adjustment under ALIGNMENT. Be sure that the panel meter is exactly on zero when making this last adjustment.

If this last adjustment has been properly made, no shift in output DC level should be noticed when OUTPUT GAIN is turned.

(d) To calibrate the recorder, refer to the chart above the MILLIVOLTS switch. This gives the values of the calibration signals for each range. Turn OUTPUT CAL to CAL A or CAL B, and set the recorder to the desired deflection by means of OUTPUT GAIN. Then turn OUTPUT CAL to OPER, and record as desired.

Fig. 5 Increase of Output Signal caused by various sized capacitors connected to the EQUAL terminals.



5. Installation and removal of plug-in inputs: The input terminals located in the lower left corner of the 303 amplifier are contained on a removable plate which covers the input compartment. This compartment provides space for the auxiliary input shunt and multipliers. Changing the input assembly is accomplished by loosening the two large knurled captive screws at each side of the cover plate and pulling the assembly out. Installation of another assembly is accomplished in the reverse manner. Instructions for the use of the available input accessories as well as the standard input are immediately below.

Regardless of the input accessory used, the shorting button will short the input.

6. General Precautions on the Use of all Input Units:

(a) Input wires should be as short as possible and well shielded in order to reduce power-line pickup as well as the pick-up of stray electrostatic fields. When the Model 303 is used at its maximum input impedance, electrostatic pick-up must be carefully eliminated. In some cases it may be necessary to shield the entire test object.

(b) If the high input resistance of the Model 303 is to be realized in practice, careful attention should be paid to the quality of insulation used in the input circuit. Ordinary rubber and plastic insulation should be avoided in favor of teflon or polystyrene. Insulation for switches, standoffs and bushings in contact with the signal lead should be made of polystryene, polethylene, ceramic, teflon or other high quality insulation material. If cables are necessary, most types of polyethlene or polystyrene insulated coaxial cable will be found satisfactory.

(c) Input grids should never be left floating but should either be attached to the circuit being measured or shorted. If this precaution is not observed, the stability of the input tubes will be upset and excessive drift may occur for an hour or so after the grids are left open.

7. The Standard Input: The standard input provides direct connection to the first stage grids through 1 meg resistors shunted by 0.005 mfd. With this connection, the input impedance is in excess of 10^{12} ohms shunted to ground by about 10 mmf and the grid current is less than 10^{-12} amperes. If single-ended input is desired, input B should be connected to ground, and the signal fed into input A. This connection allows a positive meter deflection and output swing for a positive input signal. If reversal of polarity is desired, it can be accomplished by shorting input A and using input B. Frequency response with this input is as stated in the section on OPERATING CHARACTERISTICS.

In some applications, an input balanced with respect to ground is desirable. Where this can be provided, a reduction in spurious pick-up will be realized due to the fact that the instrument will amplify an out-of-phase signal at least 100 times more than an in-phase signal. Unwanted pick-up will be largely cancelled due to the fact that spurious signals usually will be in phase on both grids. For balanced connection use both A and B terminals.

8. Model 3032 Multiplier extends the measuring range from 2.0 volts to 800 volts. The input resistance is one megohm, and the division accuracy is within 0.2%. This is achieved by using precision wire-wound resistors in the divider. The overall accuracy possible with the Model 303 and 3032 is better than 3 per cent. Multiplication ratios of 1x, 10x, 100x and 1000x are provided. These ranges are selected by a small rotary switch. By using the 800 and 2000 millivolt settings, additional ranges of 8, 20, 80, 200 and 800 volts are provided. The maximum recommended voltage input is 800 volts. The frequency response of this divider will be within 3db up to 30 kc.

9. Model 3033 Multiplier is similar to Model 3032, except that the input resistance is 100 megohms; and the accuracy of its division ratio at dc is 2%. The frequency response will be dc to 1kc. Deposited carbon resistors are used. The overall accuracy possible with this divider will be within 4%.

10. Model 3034 Decade Shunt: This accessory converts the Model 303 into a direct reading micromicroammeter.

Seven ranges are provided, in decade steps, from 10^{-6} to 10^{-13} amperes, plus Short and Open positions. Accuracy on the two most sensitive ranges is within 2%, and within 1% on all other ranges. Since the maximum error of meter indication is 2%, the overall accuracy is within, respectively, 4% and 3%.

Current is measured by recording the voltage drop across the resistor supplied by the decade shunt. Since the input grid current is less than 10^{-12} amperes, currents down to about 10^{-12} amperes may be measured with this arrangement. If measurement of lower currents is desired, the Keithley Model 210 or 200B Electrometer and 2008 Decade Shunt are recommended.

The current is read by multiplying the shunt range by the reading on the Model 303 meter in millivolts. This gives the current flowing through the input terminal to the ground terminal in amperes. The drop through the decade shunt, which corresponds to the voltage drop across a conventional D'Arsonval microammeter, is equal to voltage read on the panel meter. Keeping in mind that $I = E/R$, and E is read in millivolts, the shunt resistance values for the various ranges can easily be computed, but are shown below in Table I for convenience.

TABLE I

Model 3034 Current Range	Resistor (Ohms)
10^{-6}	10^{3}
10^{-7}	10^{4}
10^{-8}	10^{5}
10^{-9}	10^{6}
10^{-10}	10^{7}
10^{-11}	10^{8}
10^{-12}	10^{9}
10^{-13}	10^{10}

11. Use of the Model 303 with the Model 3034 Decade Shunt to measure high value resistance: Values of resistance up to 2 X 10^{14} ohms may be measured using a Model 3034 Decade Shunt and the auxiliary 200 volt tap available at the rear of the Model 303. Fig. 6 shows the method of connecting the circuit.

The value of the resistance is simply, by Ohm's Law,

$$R_{unknown} = \frac{200}{I \text{ (amperes)}}$$

I is read from the meter and shunt setting as indicated in paragraph (10) above. The voltage drop across the shunt is equal to the meter reading. Since 200 volts is used as a test potential, the drop across the shunt resistor will be less than 1% of the test potential, and it may be neglected in the calculations. If, however, lower test potential is used the drop across the shunt resistor may become important. In this case the value of the resistance to be determined is

$$R_{unknown} = \frac{E - V}{I}$$

Where E is the applied test potential in volts

V is the voltage reading of the 303 in volts

I is the current flowing in the resistor in amperes.

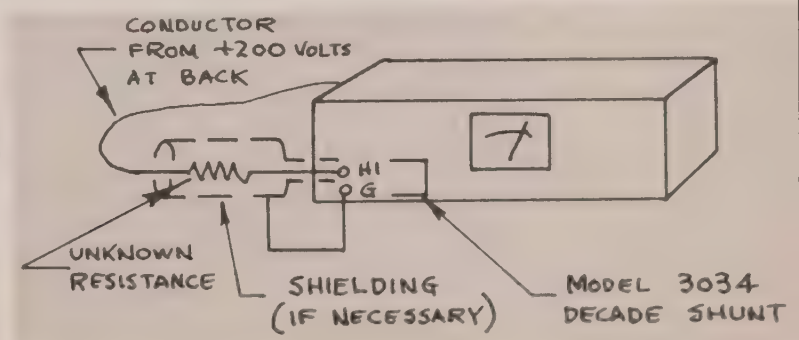


Figure 6. Measuring high resistance with the Model 303

DETAILED OPERATING CHARACTERISTICS

(a) Input Impedance: The input impedance is greater than 10^{12} ohms shunted by about 10 mmfd. The input resistance will exceed 10^{12} ohms under all conditions of operation. This is assured by the use of teflon sockets and polystyrene insulation in the first stage.

(b) Grid Current: The grid current will not exceed 10^{-12} amperes under any operating conditions.

(c) Voltage ranges are zero to 2, 8, 20, 80, 200, 800 and 2000 millivolts full scale. Accuracy of the meter reading will be within 2% of the full-scale reading.

(d) Zero setting and Zero Suppression: The amplifier may be set to its left zero meter mark with as much as one volt dc on the input terminal on any range. For example, if it is desired to measure changes in a one volt potential which amount to a few millivolts, the instrument may be turned to, say, the 20 millivolt range and rebalanced to zero in the presence of the 1 volt input. Then the change in potential would be read directly.

(e) Polarity of Operation: A meter switch permits operation of the instrument in either a plus or minus direction with no loss of linearity. Positive potential on the Hi-A terminal gives up scale deflection on the meter with the METER switch on +.

(f) Noise Level: In a bandwidth of 10 cps to 35Kc, the RMS noise as read on a Hewlett-Packard AC vacuum tube voltmeter is less than 25 microvolts. Where reduced bandwidth is acceptable, the noise figure may be reduced by means of a suitable filter at the output.

(g) Frequency Response: The high frequency 3db point depends on the working sensitivity of the instrument set by the MILLIVOLTS switch. Since the high frequency response is reduced as the gain is increased. Table II gives the frequency response for the various ranges.

TABLE II

FREQUENCY RESPONSE VS RANGE

Range	Approximate 3db Point
2000 Millivolts	100 kc per second
800 "	100
200 "	90
80 "	80
20 "	70
8 "	35
2 "	20

(h) Power Output: The output amplifier will deliver plus or minus 80 volts at currents up to 25 milliamperes up to about 10 kc. Over 10 kc, full voltage output will be obtained if the output is less heavily loaded. The internal impedance of the output is less than 50 ohms.

Powerline requirements are 50-60 cps, 100-130 volts at 120 watts. A line voltage change from 100 to 130 volts affects the gain less than 1% and causes no noticeable change in meter setting on any range.

(i) Drift: The Model 303 incorporates balanced circuitry, stable resistors, shock mounted input tubes, and well-regulated power supplies to keep the drift at a minimum.

Many factors under the control of the user, however, can be adjusted to give minimum drift. The most important is maintaining the instrument at a constant temperature. Among other things, this means that the amplifier should be turned on and allowed to come to thermal equilibrium before the most critical uses, and that the power should not be interrupted immediately before or during measurements. Ventilating fans near the amplifier should not be turned on and off indiscriminantly, and drafts from nearby windows should be avoided.

Large input signals which greatly overload the first stage tubes can cause a drift which requires several hours to disappear. Because of the high input impedance of the Model 303, a very large potential appears at the input terminals when they are open-circuited, and this unstabilizes the input tubes. This can be prevented while changing connections by connecting the input grids to ground with the Input Short switch, which has a locking position for this purpose; or, the input terminals could be grounded with external jumpers.

Excessive vibration or large amplitude mechanical shocks or bumps should be avoided. The shock mounting provided will isolate the tubes from normal vibrations but driving the isolators into their snubbers can cause a change in the alignment of the input tube electrodes. The accompanying change in electrical characteristics will shift the zero balance point.

The voltage regulators used will accept line voltages from 100 to 130 volts. Variations outside these limits will cause unreliable operation. On normal commercial power lines, no additional regulation is necessary or will be helpful. When abnormal conditions are encountered, additional line voltage regulation should be considered.

In normal operation after two hours warm-up, the drift will be less than 2 millivolts per hour. After about six hours operation the drift will be less than one millivolt per hour. Under favorable conditions where temperature change and vibration is at a minimum, drifts of less than 500 microvolts per hour are possible after about six to eight hours of operation. In applications where the lowest possible drift is desired, continuous operation of the amplifier is recommended. In cases where continuous operation is not feasible, it is suggested that an appliance timer, such as is manufactured for turning on coffee makers etc., be used to turn on the instrument several hours before use is contemplated.

The specifications quoted above for drift are applicable on any range or gain setting.

SECTION IV MAINTENANCE PROCEDURE

FACTORY ADJUSTMENTS

1. Alignment Adjustments for the output amplifier:

The purpose of these adjustments is to make the dc level of the output read zero with zero input and to prevent any change in dc level of the output when the OUTPUT GAIN control is rotated from its minimum to maximum position. These controls are screwdriver adjustments accessible from the front panel; they do not require frequent adjustment. A warm-up period of about 30 minutes should be allowed before making any readjustments. The method of alignment has been covered on page 11.

2. Adjustment of B+:

A potentiometer located on the rear of the chassis marked + 200 ADJUST is provided for adjustment of the + 200 volt supply. This setting is made at the factory to 1% and should require no further attention unless V22, the OG3 voltage reference tube, is changed. If adjustment is necessary, use an accurate meter, connected from ground to the + 200 test jack, and set to exactly 200 volts. The accuracy of the calibration signals depend on this adjustment.

3. Meter sensitivity trim:

R 157 is a 200K potentiometer in series with the meter multiplying resistor, mounted on the back of the meter. Its purpose is to compensate for variations in meter accuracy. It is set at the factory and should not require readjustment unless the meter is changed. To readjust, set instrument to the 2000 millivolt range and apply exactly 1.50 volts to the input. Set potentiometer so that meter reads exactly 1.50 volts.

MAINTENANCE AND REPAIR:

No normal maintenance is required except that the input terminals and associated wiring should be kept clean tc avoid the introduction of leakage across the input terminals.

DR 10754-D is the circuit schematic diagram and is included in the rear of this instruction book. In addition to the usual information, the circuit voltages at all important points have been listed. All voltages were measured with a standard 11 megohm VTVM.

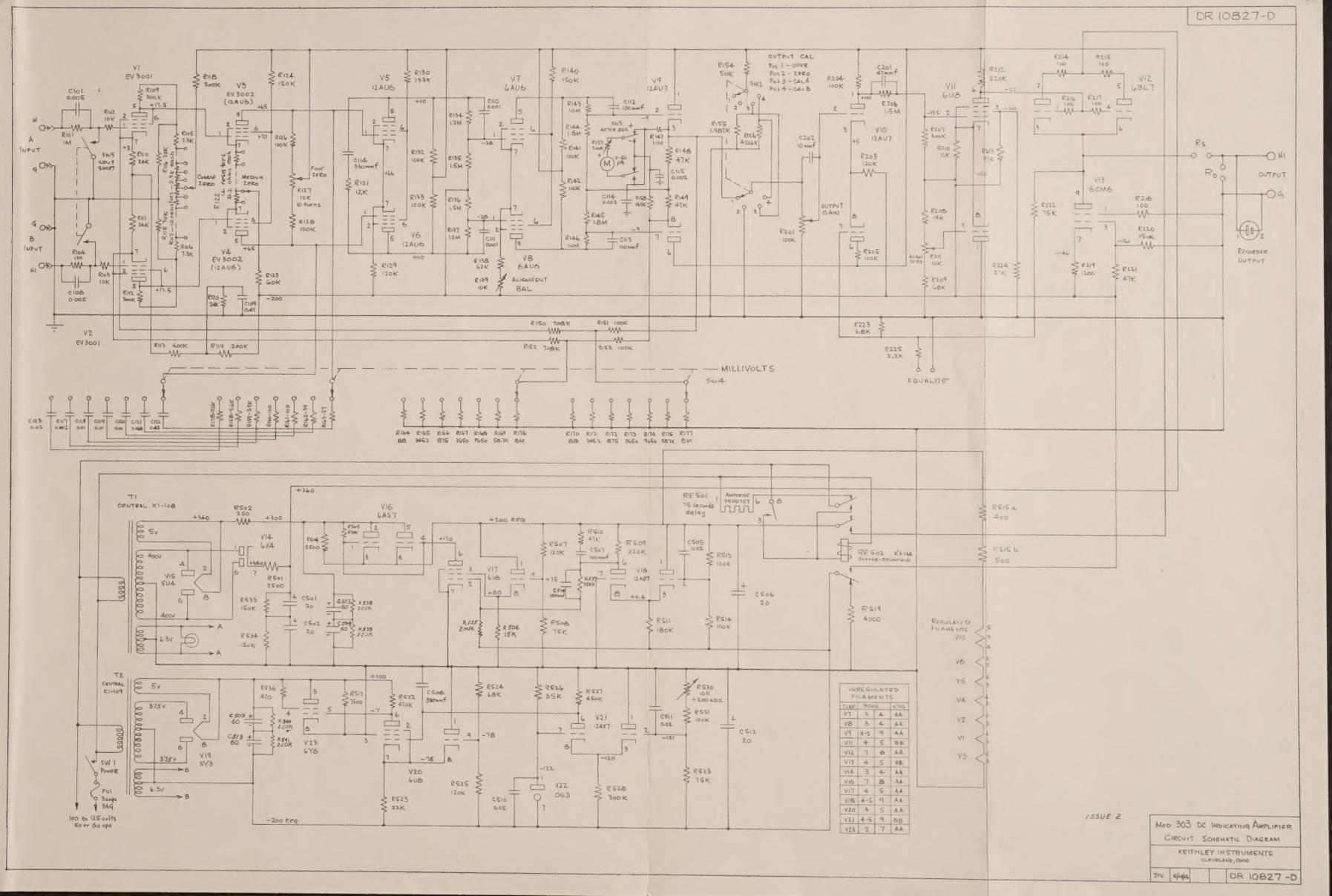
All circuits are straight forward and should present no special difficulties.

With the exception of V1, V2, V3, and V4, all tubes are standard commercial tube types. V1 and V2 are a special matched set, as are tubes V3 and V4. The careful selection of these tubes is important to the stability of the amplifier and to the in-phase rejection when using the differential input connection. It is strongly recommended that only factory-supplied replacements be used in these positions.

In case repairs are necessary, it should be noted that many of the tubes in the instrument are in a series string arrangement. If the string is interrupted, every section of the amplifier will cease to function properly. Therefore if the instrument becomes inoperative, first check the continuity of the series filament string.

The factory is always ready to make repairs if necessary.

DR 10827-D



UNREGULATED FILAMENTS			
Tube	Pins	V(ac)
V1	3	4	AA
V2	3	4	AA
V3	4-5	9	AA
V4	4-5	9	AA
V5	4	5	BB
V6	4	5	BB
V7	3	4	AA
V8	3	4	AA
V9	4-5	9	AA
V10	4	5	BB
V11	4	5	BB
V12	7	8	AA
V13	4	5	BB
V14	3	4	AA
V15	7	8	AA
V16	4	5	AA
V17	4-5	9	AA
V18	4	5	AA
V20	4-5	9	BB
V21	2	7	AA
V23			

ISSUE 2

Mod 303 DC Indicating Amplifier
Circuit Schematic Diagram
KEITHLEY INSTRUMENTS
CLEVELAND, OHIO
DR 10827-D